# Comparing offshore wind power with inland wind

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The wind debate in Delaware is now turning to comparisons of inland wind with offshore wind. This document provides analysis necessary to make valid comparisons.

I offer this analysis because I feel that the comparisons being made in recent public debate are misleading. This document compares adjustments needed for comparing offshore and inland wind resources within PJM and within the Mid-Atlantic region.

## *Background*

Seeking new generation and price stability, Delaware HB 6 mandated an RFP for new in-state generation, bids were submitted by all interested companies by December 2006, and those bids were evaluated in an open public process by four state Agencies. Bluewater Wind's bid for a 450 MW offshore wind park won, not because the Agencies wanted green power, but because the wind bid best met the legally-mandated criteria of the RFP, including weighted scores for long-term price, price stability, use of new technology, environmental benefit, and so on. Subsequently, Delmarva Power and Bluewater Wind produced a contract, a power purchase agreement (PPA), to buy power for 25 years at a 2007 price of $98.93 per MWh (or $105.60/MWh if capacity charge is included), with a 2.5% inflation factor. This PPA will not take effect unless the state completes the HB 6 process and directs Delmarva Power to sign it.

Delmarva Power issued a new RFP for wind power contracts in Feb 2008[1], and now the resulting preliminary on-shore wind offers are being compared with the in-hand contract for offshore wind power from BWW. Such a bidding is a legitimate way for Delmarva Power to meet its legally-mandated requirement to have renewable energy certificates (RECs) (under a separate law) prior to production from the Bluewater Wind project. By analyzing the new RFP bids with the HB6-determined bid winner, I am not taking a position on whether or not it is legally or contractually legitimate to offer these new preliminary bids as a substitute for the result of the HB6 auction, nor more generally whether it is appropriate or lawful to interrupt a legally-mandated process with an *ad hoc* process.

A single-page summary of the new bids was released on April 8, 2008, which gave prices for inland wind of $77.3/MWh from PA and MD, and $62.20 from IL and IND. This same sheet incorrectly cited the price of power from Bluewater Wind as $123.98 (the correct price is $98.93; RECs are a separate decision). Immediately two things are odd about these distant wind prices. First, these figures are much lower than prices cited in testimony before the Senate Energy & Transit Committee by reputable large wind

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[1] Request For Proposals for Renewable Wind Energy Generation, Delmarva Power & Light Company, Issue Date: February 14, 2008

suppliers like Iberdrola. So, what was the entire range of bids, and who are these bargain-price bidders? Second, Delmarva Power has been purchasing power for about \$110/MWh in annual bids. If wind were actually available for \$62 to \$77/MWh, why wasn't Delmarva Power buying wind previously, rather than local dirty power for \$110?

## *Resource availability*

Delaware has very little economically-viable wind on land. Figure 1, from AWS Truewind (available on [www.ocean.udel.edu/windpower](www.ocean.udel.edu/windpower)) shows the wind resource in our region. Roughly speaking, the blue and read areas have strong enough wind to be worth developing.

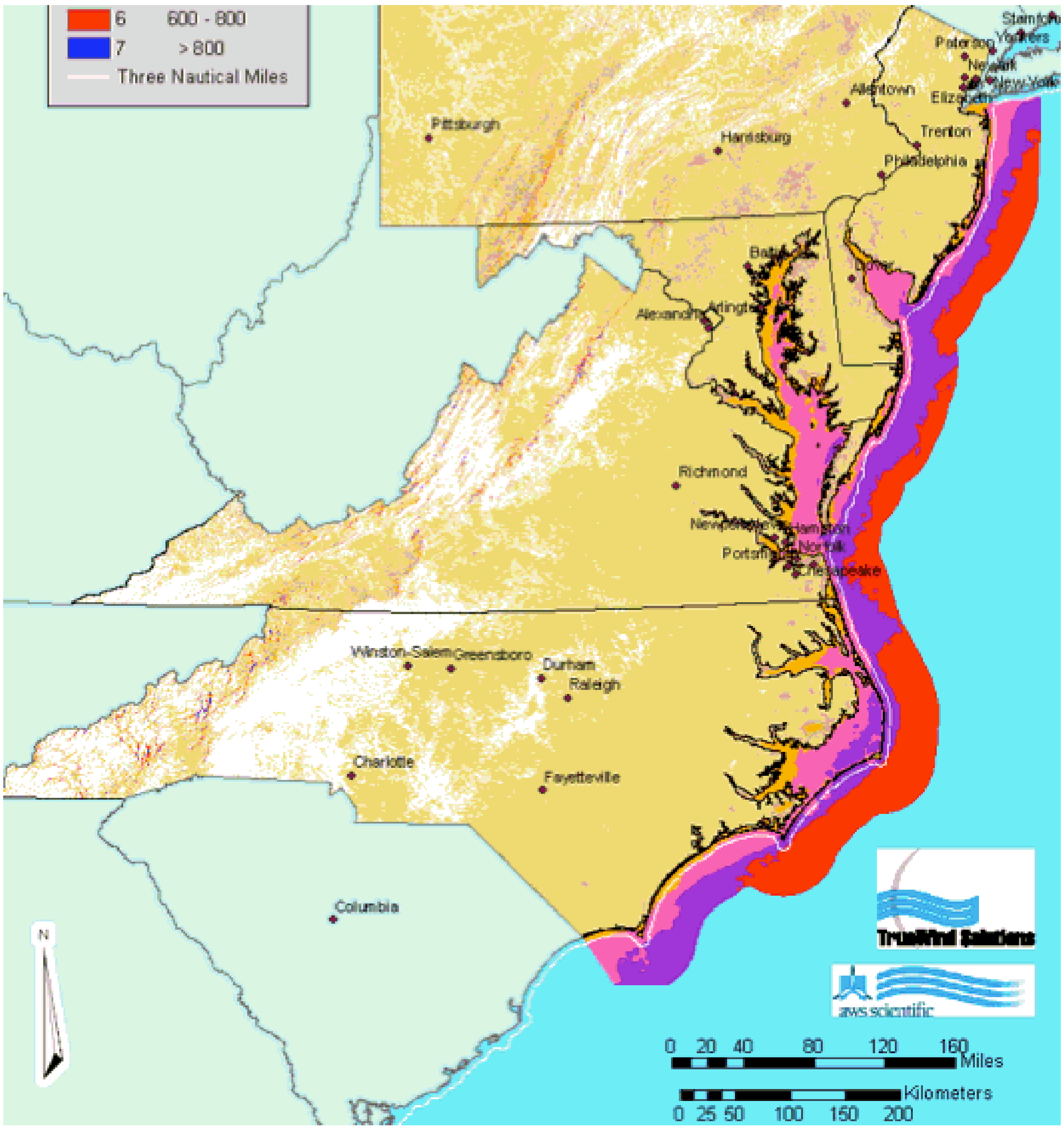


Figure 1. Wind resources of the mid-Atlantic, offshore and onshore (from AWS Truewind).

On land, the red high-wind areas are the thin lines running along ridge tops. The map shows that our region's main wind resources are offshore. Not all the good land sites are used yet, and a turbine placed in an inland red area will produce the same amount of power as an ocean red area, at less cost per MWh. However, without considering transmission costs, time of day of generation, and intermittency, comparing only cost per MWh is misleading.

### *Moving power, at a cost*

The above-noted geography of wind in our region means that we have the choice of getting nearby wind offshore, or far away wind on land. The PJM "grid", of which Delaware is a part, allows power to be moved, and to be bought and sold throughout the PJM region. Nevertheless, this comes at a cost. Recent bids for wind power in other states are always very careful to specify that the wind bidder must either build transmission to bring the power to the buyer, or sign transmission contracts, and/or that the cost of moving that power must be included in the price of delivered electricity. One example is the "2008 Wind Resource RFP" by Public Service Company of Colorado[2], issued 11 March 2008. A second example is the RFP for renewable electricity from Pacific Gas and Electric[3]; like Delmarva's RPF it accepts offers from anywhere within their ISO. But unlike the Delmarva RFP, they require bids to explicitly include the cost of transmission, even from within their own service territory. Even though the territories of these bids are much smaller than PJM (PSCo and CalISO), they both note that transmission costs can be "substantial" (PG&E bid, pp 32 -42), and can "hinder the development of economic proposals" (PSCo bid, Appendix A). Why is this not even mentioned in the Delmarva Power RFP, which allows a far larger territory?

In comparison to the emphasis on transmission costs in these other wind RFPs, the Feb 2008 RFP from Delmarva requested price quotations at the point the power entered the grid. That means that bidders could offer to deliver wind power to West Virginia, Western Pennsylvania, or even the Western border of Illinois, yet according to the Feb 2008 Delmarva RFP, the wind power provider can still quote the price of electric power as delivered at that distant point.

The PJM system does allow for transmission, even across the entire system. However this comes at a cost. Within PJM, if one does not own transmission, that cost is reflected in the Locational Marginal Pricing (LMP). LMP reflects that power is less valuable in some places (e.g. because of an excess of low-cost generation) and higher value in others (e.g. because of a surfeit of generation and/or insufficient transmission to those areas).

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[2] http://www.xcelenergy.com/docs/PSCoWindRFP.pdf

[3] Renewables Portfolio Standard, 2008 Solicitation Protocol, February 29, 2008. http://www.pge.com/b2b/energysupply/wholesaleelectricsuppliersolicitation/renewables2008/

Delaware imports about 1/3 of its power, and has some constraints in transmission. Correspondingly, Delaware's 2007 average LMP was $7.35 above the PJM average energy price.[4] Thus, if wind power was sold for $80 and injected at an average point on the PJM system, we would pay $87.35 for it in Delaware. But the bulk of the bids revealed do not come from average points in PJM. They come from Indiana and Illinois, PJM areas that are the opposite of Delaware, and have excess power. Thus, they have a negative adjustment to average LMP. For example, wind injected in the AEP zone, in Indiana, would have an additional LMP charge for adding power there, $9.15 in 2007[5], so that wind purchased in Indiana and sold in Delaware would have a total LMP addition of $16.50. See table below (prices are $/MWh). Thus, it is very misleading to cite wind prices in Indiana without including the LMP difference, which is essentially a charge to bring that power from Indiana to Delaware.

| State | Zone | LMP Difference | LMP Adder to generate there & deliver to DE |
|---|---|---|---|
| Delaware | DPL | $7.35 | $0 |
| Illinois | ComEd | -$9.25 | $16.60 |
| Indiana | AEP | -$9.15 | $16.50 |
| PA/MD | AP | $0.28 | $7.07 |

An added concern on transmission, reflected in the yearly LMP price fluctuations, is that there are no long-term contracts to guarantee the LMP adder. If transmission becomes more constrained, if we do not build more power plants in Delaware to keep up with demand, and/or if some of our existing fossil plants are shut down, the LMP adder will get bigger. LMP is an added source of price instability, which is one of several reasons that HB 6 called for generation to be in-state.

These are 2007 prices; the prices could go up or down in the future. Because the LMP adder is subject to market prices, trying a long-term contract to distant sources, subject to fluctuating LMP prices, is not consistent with price stability. On the other hand, if we were obligated to buy distant out-of-state wind via a long-term contract, and if LMP pricing keeps increasing, Delaware would need more transmission. Thus a long-term obligation to buy power from far away could be used in the future to justify new investments in transmission.

Nevertheless, today's adder is probably smaller than the lower cost of inland wind (even if we saw the full set of bids rather than just the bargain basement bids shown so far). Thus, the quoted prices for wind purchased elsewhere in the PJM system, even adding transmission or LMP at today's prices, would still have a lower price per MWh. But this is not yet the whole story.

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4 PJM, "2007 State of the Market Report", Table 2-72. For DPL zone.

5 ibid

## *Time of day value of wind power*

Different meteorological forces determine wind on land, wind on the coast, and wind on the open ocean. Therefore, they have different profiles by time of day. Figure 2 is from an accumulation of sites on land, shown in a recent presentation by PJM[6] to illustrate the problem that onshore wind is stronger during the nighttime. The problem is that load (the demand for electricity) is greatest during the day.

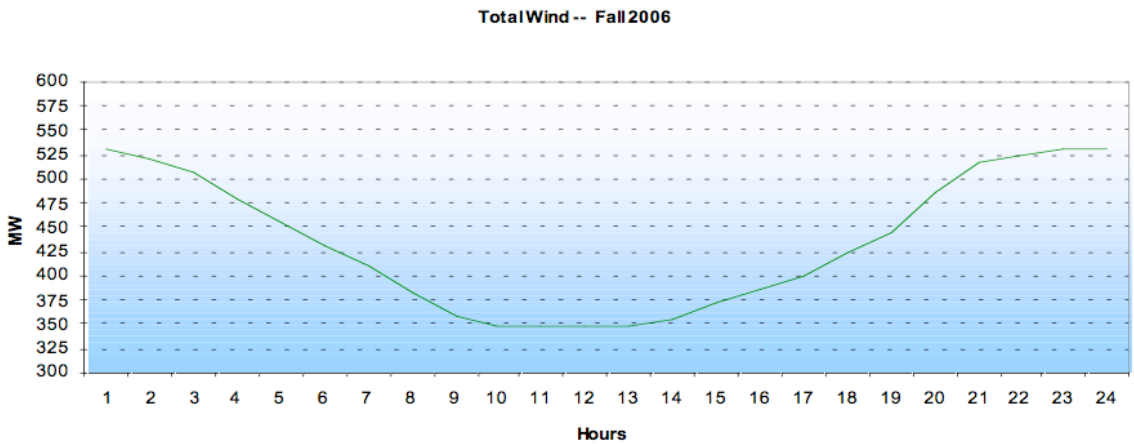


Figure 2. Land based wind generation tends to be inversely correlated to daily load curve (PJM, 2008).

The problem with the inland wind power generation profile is that the period of greatest output, in the nights and early morning, is exactly the time the power is least needed. The top half of the generation curve is 20:00 to 4:00 hours (8 pm to 4 am). As shown by Figure 2, the difference is large—almost twice as much electricity at night as during early afternoon. Figure 3 shows the value of power at these different times of day in the PJM area.

[6] Kevin J. Komara P.E., Presentation at Washington International Renewable Energy Conference, Official Side Event, Washington, DC, March 6, 2008

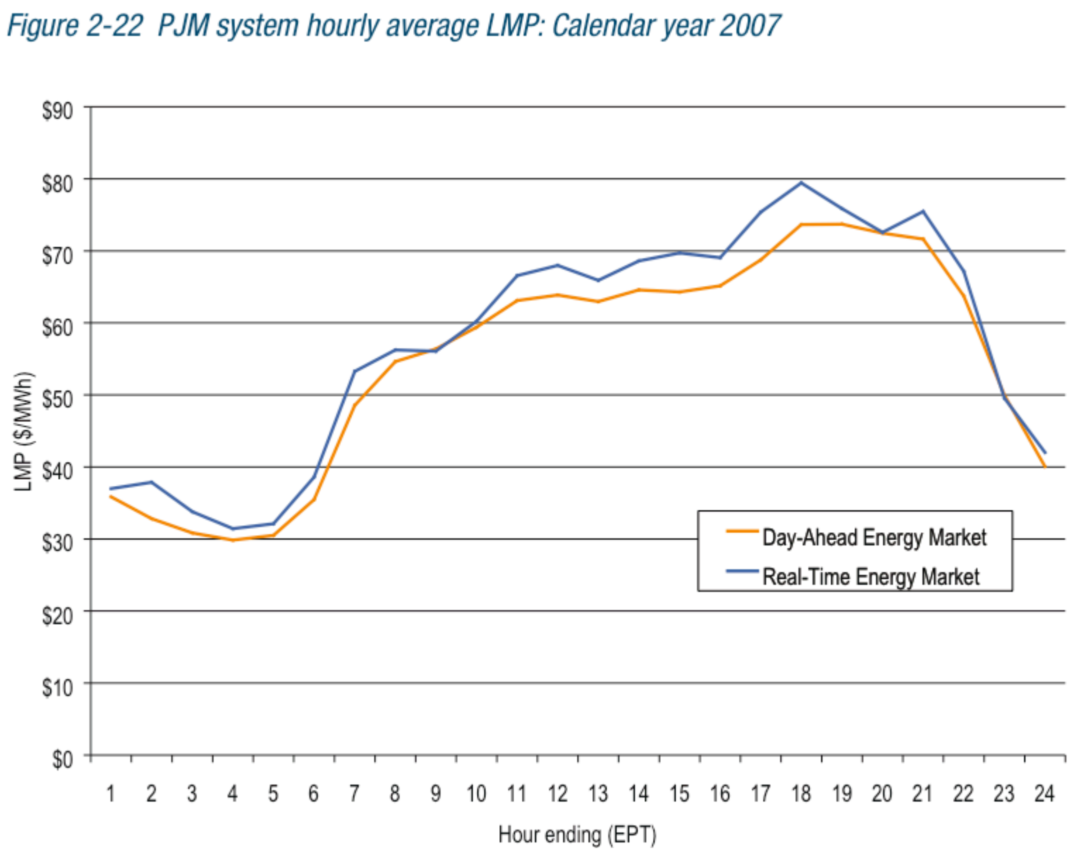


Figure 3. PJM system hourly average LMP: Calendar year 2007. From 2007 State of the Market Report, Part 1, PJM Interconnection, Figure 2-22, p 63.

By comparing Figure 2 and Figure 3, we see that the times of maximum inland wind generation are the times of lowest power value. The difference in value is significant—when inland wind is strongest, the value of the power is only half as much.

The poor time profile for inland wind is quite different from that of wind on the coast, in bays, or in the open ocean. Figure 4 compares the time profile of these three, based on meteorological station wind measurements for 3 to 20 years, adjusted to turbine hub height[7]. Atlantic City is a coastal site, just a little landward of the beach (there is in fact a 7.5 MW wind generator there). Brandywine Shoal is within the Delaware Bay, and EB44009 is a NOAA buoy anchored to the continental shelf, in the open Atlantic Ocean off the Delaware coast. Buoy 44009 is close to the proposed Bluewater Wind site.

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[7] Richard W. Garvine and Willett Kempton, "The wind field over the continental shelf as a resource for electric power", Manuscript, 29 September 2007, College of Marine and Earth Studies, University of Delaware.

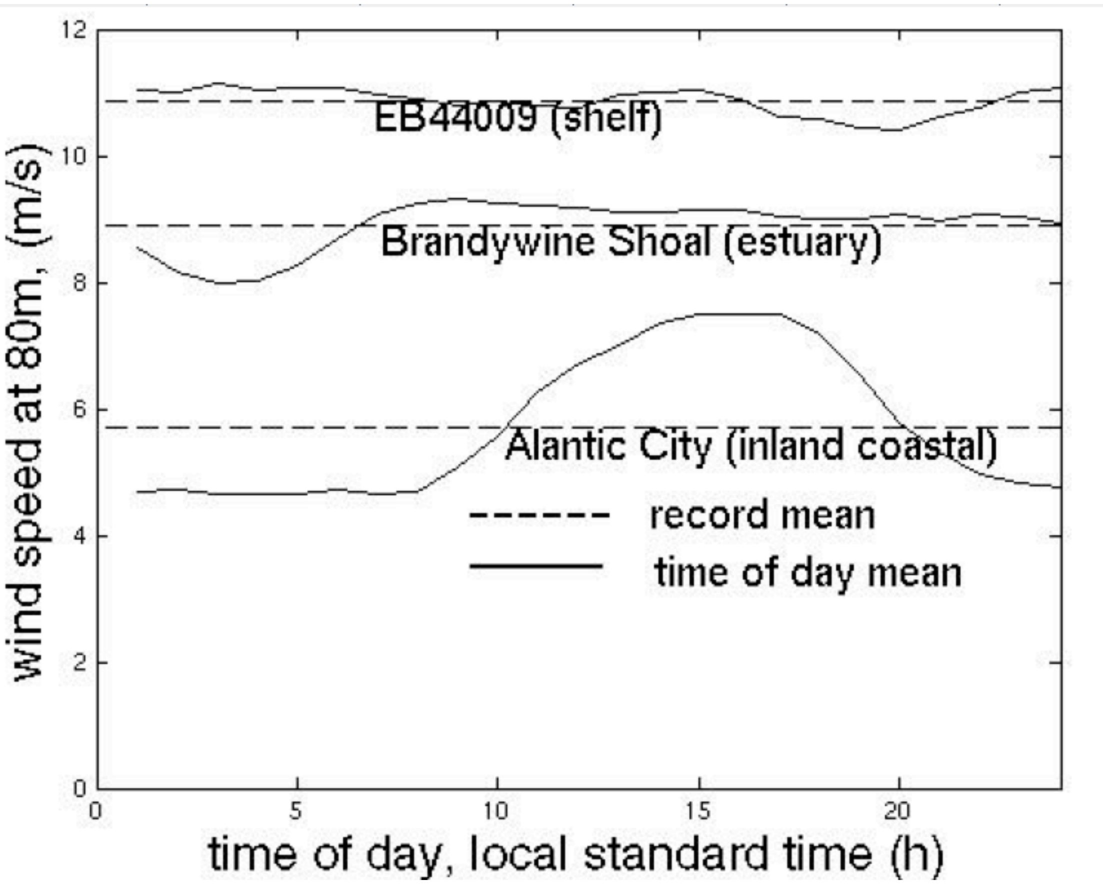


Figure 4. Time of day wind profiles for coastal, estuary (Delaware Bay), and ocean sites. From Garvine and Kempton, 2007. Ocean site EB4409 is approximately at the Bluewater Wind proposed site.

By time of day, the Atlantic City (coastal) site is ideal. Due to the "sea breeze" (driven by ocean/land thermal differences) the times of high generation match the need for power nicely. The estuary site is relatively uniform during the day, and the ocean site out on the continental shelf has even more uniform power output. The ocean shelf site also has much stronger wind, so even though the coastal site has a better time of day match, the ocean site is better because there is more power from the ocean site at all times. (The figure shows averages of many days—of course on any one specific day, any one of the sites could have the most wind.)

The time of day comparison of Figures 2 through 4 tells us that in our region, two-thirds of the inland wind generation will be at the times when that power is worth half the price. The ocean wind is produced approximately equally at all times of day. This means it is misleading to compare the cost per MWh of inland and offshore wind power. Given these time and price relationships—2/3 of energy is generated when power is worth ½ the price—that means, even if both wind sites produce exactly the same number of MWh, the cost of power from the land site should be have a 12% adder (that is, multiply the inland price by 1.12) to account for the inland wind power being produced when it is less needed and less valuable.[8]

### *The bottom line for financial comparisons*

The above adjustments for transmission and time of day use allow more direct financial comparisons of inland wind with offshore wind. The BWW contract is $99 per MWh (or $105.60 for energy and capacity). At what price is inland wind comparable? Assume the wind is purchased in Illinois or Indiana and sold in Delmarva, for an LMP differential of $16. The time of day multiplier of 1.125 applies to energy plus transmission/LMP. We can see that the price of inland wind under these circumstances is $73. That is, inland wind at $73/MWh has the same cost and value as offshore wind at $100/Mwh. To confirm this, we calculate

($72/MWh + $16/Mh) * 1.125 = $99

So, if we are considering only direct financial cost, $72/MWh of Indiana or Illinois wind will cost consumers the same as $99/MWh Delaware offshore wind.[9]

The above factors allow a comparison of the reported bids from inland wind, delivered to Delaware and accounting for inland wind being predominantly at night.

PA and MD $77.3/MWh + $7.07 * 1.12 = $94.49 BWW equivalent

IN and IL $63.20/MWh + $16.55 * 1.12 = $89.32 BWW equivalent

The above are direct cost to consumers for wind power. The above does not reflect my suspicion about these apparent "bargain basement" bids having been selected from a larger but not-revealed set of bids. On the other hand, the above does not consider that these bids appear to include RECS (that is a separate purchase decision), nor does it reflect either the inflation adjustment of BWW nor the expected increase in Delaware LMP if no new generation is built in-state. I submit that despite these incomplete aspects, my above "BWW equivalent" prices are a more fair comparison than the prices released on the April 8, 2008 "Summary sheet."

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[8] The 12.5% adder is calculated as follow, for a hypothetical example of wind being worth $100 during the day and $50 late at night, average $75/MWh. For offshore, the value of 24hrs of MWhs is 1/2*$100/MWh+1/2*$50/MWh=$75/MWh. For onshore, it is 1/3 x $100 + 2/3 x $50 = $66.66/MWh. Thus to make the price per MWh comparable, we multiply the onshore price by $75/$66.66 or 1.125. That is, a 12.5% adder makes the two of equal value.

[9] If data on a specific site is available, this comparison can be refined. For example, knowing the wind profile at a specific bid site could refine the 12.5% multiplier, and knowing the injection node would refine the current LMP adder (but how much transmission costs will change in the future would still be unknown).

## *Inland wind more erratic*

Three additional factors affect price, but I cannot calculate an exact dollar cost for them. These are the less steady wind inland, the effect of new in-state generation in lowering all prices, and the health benefits of additional in-state generation.

To approximate the steadiness of wind in this area (for which I have no public data available), I use data from a collection of inland wind generators, from Germany.[10] Figure 5 shows the entire E.On control area, which would be expected to be smoother due to geographical dispersion of multiple sites. The output is very erratic; this is partly just due to the lower wind capacity factor. (The graph is not ideal, since it shows wind as a % of load rather than direct wind output.). Figure 6 shows a typical offshore wind profile, in this case from Brazil offshore. In Figure 7, I clip the offshore output to make an approximation of the power that would be seen by Delmarva. Specifically, Figure 7 shows 90 days of output from a wind farm (maximum 450 MW in BWW case, labeled as 5000 kW in the Brazil graph), clipped at 2/3 of peak (corresponding to the Delmarva 300 MW max for the contract).

This is why E.On complains about wind variability, and why it would be better if they had a single wind farm in the ocean, especially with the clipped profile of Figure 7, as provided in the Delmarva Power contract. This is actually a somewhat surprising conclusion. This conclusion would not be general to all land-based regions, one much larger or one more internally diverse than E.On (e.g. the entire US great plains) would be different.

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[10] From E.On, 2005, *Wind Report*. Figure is the Entire E.On power output profile, p 5. Found at: http://www.wind-watch.org/documents/wp-content/uploads/EonWindReport2004.pdf)

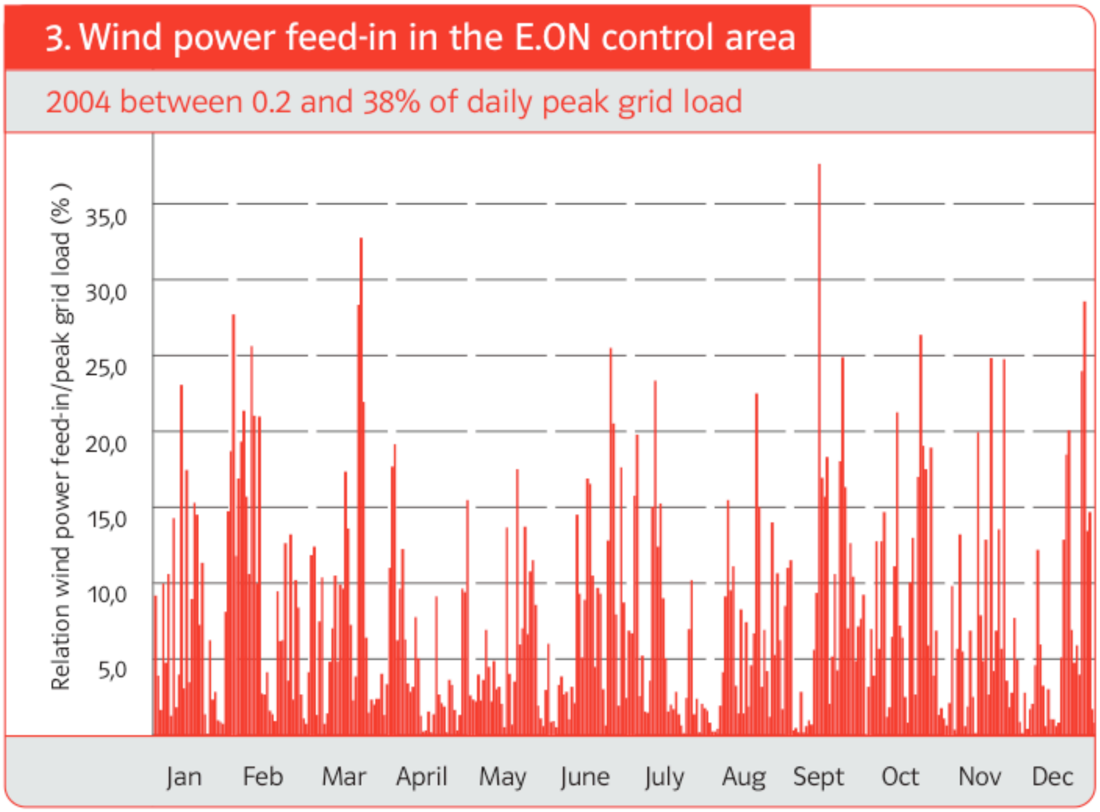


Figure 5. Inland wind power profile, from the E.ON control area.

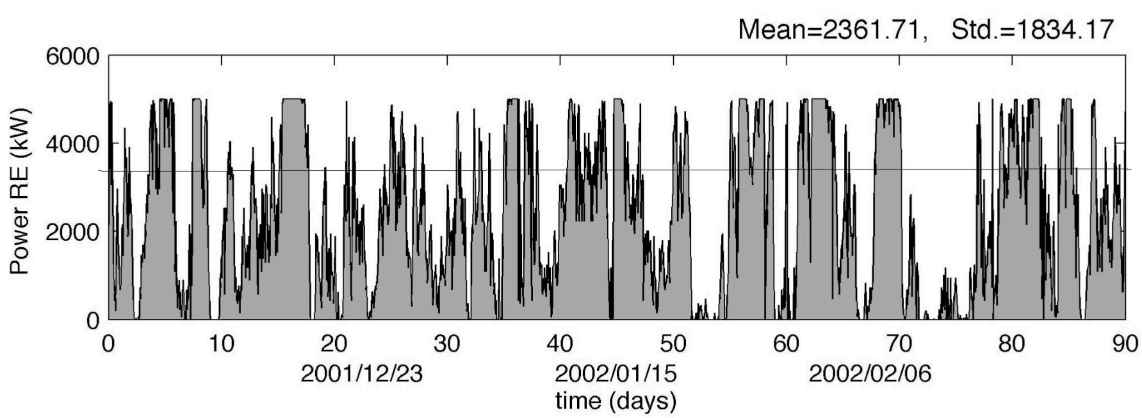


Figure 6. Calculated offshore wind output power.

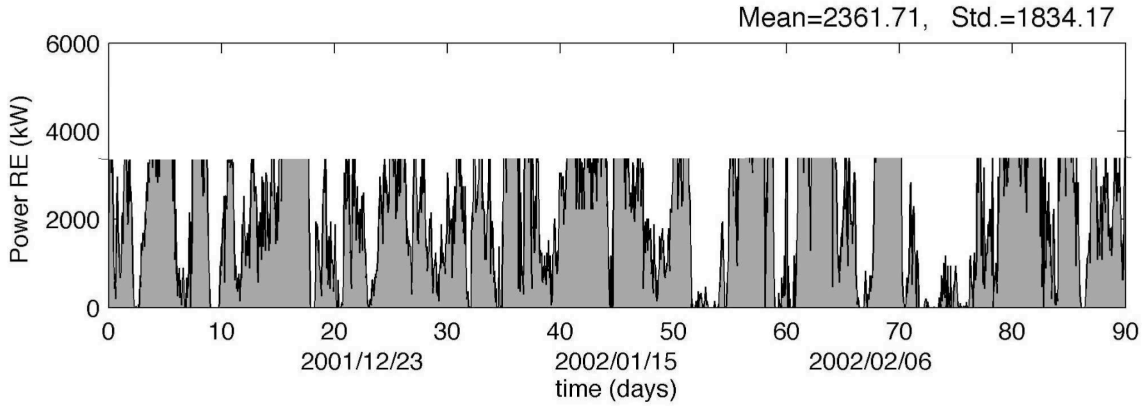


Figure 7. Calculated offshore wind profile from Figure 6, with the top 1/3 clipped off. This simulates the BWW contracted power delivered to Delmarva Power.

Although the more erratic nature of inland wind cannot be assigned a specific cost, it will be more difficult to manage. As Figure 5 shows, adjustments in power from other plants would be needed considerably more often for the inland sites than for the BWW contracted power, simulated in Figure 7. Thus inland wind power may be more difficult to manage. This may have a direct cost impact on customers, although probably less than $10/MWh.

## *Other Economic Factors*

Injecting 450 MW of new power into the Indian River node, as proposed by BWW, will reduce both the electric and natural gas prices on the peninsula. This is because spot market power is sold on a "market clearing price" basis (if the highest price bid is not needed, all buyers pay less), and because of the LMP pricing mentioned earlier. By lowering the demand for electricity, especially in winter, the demand for natural gas is also reduced and this improves supply of natural gas available for home use, heating and industrial use, again lowering price. These price benefits would not accrue to Delaware (or would be smaller, depending on contract terms) if wind power were out of state.

Injecting 450 MW of new power into the Indian River node, as proposed by BWW, will also provide health benefits to Delaware and to the region. There was some very misleading testimony before the Senate Energy and Transit committee that the BWW project would only reduce generation in New Jersey, not in Delaware. This may have been due to the mistaken assumption that Indian River is operated on base load, like many coal plants. In fact, Indian River units 1 through 4 were in 2007 operated at heat input capacity factors of 44%, 48%, 52%, and 38%. [11] The Indian River units operate at least many hours on an economic dispatch basis, which means that new generation will reduce the number of hours they operate, thus yielding a health benefit in the immediate area. The analysis on the PSC docket by Levy and Kempton estimates a total health

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[11] US. Environmental Protection Agency, Acid Rain Data (certified/QAd/QCd).

benefit of $750 million over the life of the project, if BWW is built. Some of that will occur in Delaware, other parts will occur downwind of other power plants in the region. Because Delaware already purchases about 30% of its power from outside the state, buying wind power will essentially eliminate health benefits within Delaware, and reduce those in the region. The $750 million is a real savings in the health system, services, and human misery, and it appears to be larger than any additional cost of power from the BWW project.

This document has quantitatively addressed price differences between inland and offshore wind. Some will consider other reasons (e.g. economic development in an industry growing at 35%/year, job development versus exporting jobs, climate change, etc.) equally or more important. Although I agree that those are important, I do not address those here.

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